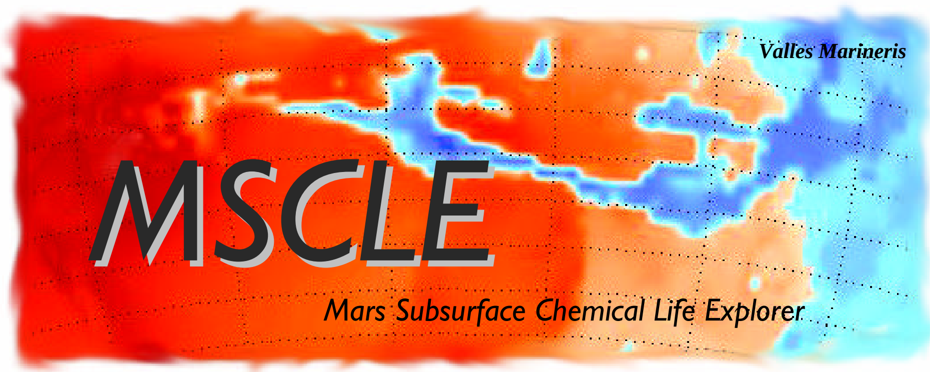

Mars Scout Mission
Progress Report
NASA Academy 2004 GSFC

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List of Figures

List of Tables

Abstract

As the next formidable step in Mars exploration, the search for life continues. The Mars Subsurface-Chemical Life Explorer (MSCLE) will dive beneath the basalt of Valle Marineris in an effort to uncover signs of past and present habitability. Three spectrometers, complemented by another biochemical analysis package, will vanguard this study. A drill mechanism will achieve the required depths for science, but the total payload will remain immobile upon reaching the Martian surface. In conjunction with this primary objective, a meteorological package may be utilized to sample the atmospheric conditions near the surface-breaching point. The platform modification for this additional resource is under consideration. To fulfill a third objective of visually imaging the Martian terrain in Valles Marineris, a high resolution camera and mobile architecture are required. If only MSCLE's primary mission is accomplished, the heart of Mars will see the light of day and new methods of investigation will gain credence and experience. Further, with an aggressive public outreach program, human life *here* will continue to benefit from the search for life *there*.

Executive Summary

In developing a comprehensive Mars Science Effort (MSE), the science team has compiled and digested mission histories, scientific background, and instrumentation concepts. To produce a viable project within Scout Mission constraints, they've chosen an honorable goal and the next logical scientific and technical step of subsurface chemical analysis. In accordance with the scientific requirements, the engineering team is designing a novel and workable platform architecture, considering several options to gain subsurface access. Laser and acoustic drilling, along with small digging robots are among the more exotic methods. Risk mitigation lives next to boldness and imagination in every Research Associate pouring his/her effort into this mission.

It is the full intent of the MSCLE Team to produce a detailed advance concept study, designing every aspect from launch to Martian landing to end-of-life (EOL), including graphical design. In addition to the final project report and presentation, a public outreach project will help to culminate the mission research. Moreover, this PI-class mission design will provide sufficient detail and arouse sufficient scientific motivation to be a viable option for the 2011 or 2013 Mars Scout Program launch opportunity.

Overall Mission Constraints

The most general and top-level constraining guidelines are as follows:

1. Maximum of nine-year window from research and design to launch
2. Nuclear Power is not available
3. Cost cap: $450M US

Science Team

Mission Objectives

The primary goal of the 2004 Goddard Space Flight Center NASA Academy scout mission to Mars is to search for present and past life in the subsurface rocks of Valles Marineris. In order to reach this goal, the Science Team has requested three instruments. In order of importance, they are: a mass spectrometer, a neutron spectrometer, and a gamma-ray/x-ray spectrometer. These instruments will eventually be complemented by a set of chemical and biological analysis packages to ascertain the presence of life in extracted rock samples. The secondary goal is to sample the atmospheric conditions in the vicinity of the subsurface area with a simple meteorological package. The tertiary goal is to more intricately detail the rugged terrain of Valles Marineris with visual imaging.

Scientific Background for Objectives (KG, SC)

History

Onboard the spacecraft of the Viking spacecraft was a gas chromatograph to search for organic molecules in the upper, shallow layers of soil. The device used pyrolysis to heat soil samples to 500°C to analyze the gases that were released in hopes of finding organic material. The results were negative, and it was concluded that the upper layer of regolith was too oxidized for organics to survive. Viking also took atmospheric measurements, and it found that carbon and oxygen isotope ratios were very similar to terrestrial values. On the other hand, it found that nitrogen, argon and xenon ratios were very different, which lead to the conclusion that the atmosphere evolved differently than that on Earth. Although this data was useful in analyzing Martian meteorites that scientists have collected on Earth, future measurements will allow more accurate isotope ratios of noble gases and major atmospheric species in order to constrain atmospheric loss on the planet.

Prospects for Life on Mars

Valles Marineris is an intriguing target for scientific study, and one particularly interesting aspect is its unique mist clouds. There are several possibilities of why ice clouds form over the Mariner Valley, including heat release from rocks and water condensation release from shady regions of the canyons that evaporate when exposed to the Sun. The presence of water makes this site suitable for life to survive, and the best opportunity for finding life would be closest to the Noctis Labrinthus area, the East Side of Valles Marineris, heading toward the Tharsis Region. This is where we will concentrate our efforts.

The closest area to Noctis Labrinthus that is feasible for landing with current technology is the Melas Chasma location. This area is approximately 349.242-km wide, 8.890-km deep, and has a length of approximately 604.197-km, and is the top choice for a landing site. An alternative low-risk landing site is Candor Chasma, which lies close to Noctis Labrinthus and Melas Chasma. This site is approximately 297.999-km wide, 7.170-km deep, and has a length of approximately 645.822-km.

Extremophiles are the primary primitive forms of bacteria that are adaptable to live in harsh conditions, and microbiologists think that extremophiles are our oldest ancestors. Scientists have found some extremophiles that live deep below the Earth's surface, and they are thought to have lived long before oxygen was present in our atmosphere. Nanobes, for example, are a tiny species smaller than bacteria, only 20-150 nm long (about the same size as viruses) that were discovered four years ago, three miles below the seabed. *Deinococcus radiodurans* is a super-strong bacterium that can withstand 3,000 more times radiation than a human being. They are commonly found in cow and elephant dung. These are the types of organisms that may be living in the subsurface of Mars in the Valles Marineris region. Several instruments are needed to study the chemical compounds released by these life forms and any DNA signatures they may release into the atmosphere.

Figure 1: Mars Global Surveyor image of clouds in Valles Marineris from Astronomy Picture of the Day

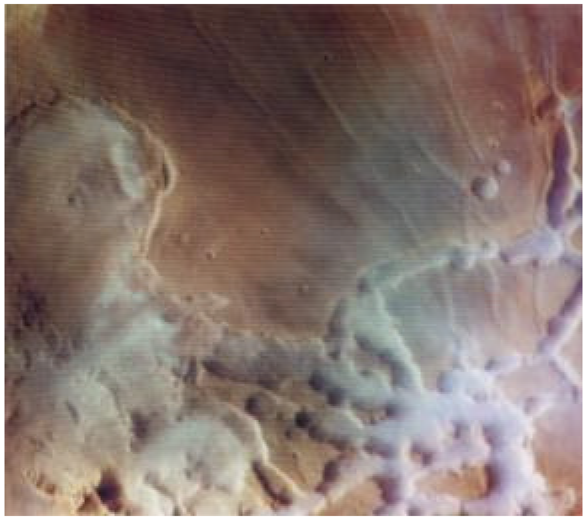

Figure 2: Water ice clouds in the Noctis Labyrinthus region from APOD 4/17/01

Primary Objective

The primary objective is to search the subsurface rocks of Valles Marineris for life. Analysis of the chemical composition of the rocky material is the most critical aspect of the mission and, as a result, both accurate and broad analysis is required. This will be completed through the four following procedures.

Characterization with Mass Spectrometry

The mass spectrometer will enable us to measure the ratio of C^{12} and C^{13}. This is essential for detecting life, as biological processes preferentially use the lighter of the two stable isotopes of carbon ^{12}C and ^{13}C. Hence, the ratio of the two stable isotopes gives us a clue of the type of life processes (e.g. photosynthesis, methanogenesis) which have resulted in the fractionation.

Furthermore, this instrument may be used to detect traces of methane. If there is an active form of life on Mars, it is most likely in the form of micro-organisms like bacteria that gain energy from the reduction of carbon dioxide to methane. The methane eventually finds its way into the atmosphere where it is readily destroyed by chemical reactions. Thus, if methane is detected, even at very low levels, this could be a sign of life.

Characterization with Neutron Spectroscopy

A neutron spectrometer is designed to record neutrons scattered off of nuclei of rock elements. It can determine soil humidity and humidity variation in a rock from a sample that is about $0.3m^3$ in volume. It can also determine depth variation of rock density.

Characterization with Gamma Ray and X-Ray Spectroscopy

A gamma-ray spectrometer records the gamma-rays of natural radionuclides: K, Th, and U. The spectrometer has the capability of measuring the elemental composition of Martian rocks and can specifically find abundances of H, Na, Mg, Al, Si, K, Cl, Ca, Ti, Mn, Fe, Th, and U. When the gamma-ray source bombards the sample, the rays interact with the sample producing gamma rays characteristic of the nuclear energy levels of a given element.

An X-ray spectrometer is designed to determine the elemental composition of subsurface rocks, including the abundance of rock-forming elements, such as Mg, Al, Si, Ca, Ti, and Fe, volatiles, such as S, Cl, and minor elements. By bombarding samples with X-rays from Fe^{55} and Cd^{109} sources, low atomic number elements produce X-ray fluorescence. The fluorescence is characteristic for a specific element and reveals the mineralogical composition of the sample.

Characterization with Chemical and Biological Analysis Packages

Search for biological response. Experiments include those similar to the pyrolytic response, labeled release, and gas exchange experiments flown on Viking. Sterilized soil samples will be used as controls. The experiments will use modern, more sensitive equipment to avoid the ambiguities that plagued the Viking experiment.

Search for chirality. A system for detecting a bias in chiral organics found in the soil will be included. Presence of a bias for one enantiomer over another of an organic compound suggests the presence of a biological system.

In-situ wet chemical analysis. A system for directly detecting specific biological compounds, such as amino acids, will be included, possibly in the form of a MEMS "lab-on-a-chip".

Table 1: Atmospheric Characteristcs to be Measured

Temperature	Temperature extremes, spatial gradient, daily change
Pressure	Atmospheric pressure at surface, spatial gradient
Humidity	Absolute and relative values for determination of water content
Chemical Composition	Determining presence of water, life-signature molecules (i.e., methane, which is a byproduct of life, but easily destroyed
Wind	Velocity vectors in conjunction with cloud-coverage affects

Secondary and Tertiary Objective

The second scientific objective was prompted by the necessity to understand the atmospheric conditions of Valles Marineris and its effect of the habitability of the land where life may be present subsurface. Figures 1 and 2 illustrate clouds that are believed to be made of water crystals. The clouds are present in the morning and dissipate during the day, and Noctis Labyrinth is one of the few places where clouds overflow the canyon walls and spill onto the surrounding plateau. We would like to try to fully understand the mechanism behind this cycle.

The third scientific objective is to map Valles Marineris pictorially. Valles Marineris has not been extensively mapped, and the best resolution from

Mars Global Surveyor Mars Orbiter Camera (MGS MOC) is around 5-6 meters/pixel. While this is excellent resolution, it can only detect structures that are larger than 6 m, and the MER's discovery of "blueberries" indicates that there are scientifically interesting structures on much smaller scales. Additionally, the imaging will further map the walls of the canyon. The pictures may reveal different rock layers

in the canyon, areomorphological features, and the way in which the clouds change over time. The camera will also be very useful in planning future Mars missions' landing sites.

Instrumentation (JD, LB, JM, FD)

Our primary science objective requires three instruments: the mass spectrometer, the neutron spectrometer, and the gamma-ray/x-ray spectrometer. The secondary scientific goal entails the use of a meteorological package or a suite of small instruments. The tertiary goal simply needs a camera ready for interplanetary missions. The Instrumentation Group of the Science Team has researched successful, unsuccessful, and theoretical missions in order to find the specifications of each of the instruments, which are detailed below. Included is a microscopic imager, which was initially included as an instrument to fulfill the first goal, yet was relinquished due to its lack of necessity.

Below are specifications for the instruments we intend to include based on previous space missions.

Mass spectrometer

The design for Beagle 2's mass spectrometer is a 90° sector instrument having a magnet of less than 1 kg made from a rare earth metal alloy and an ion pump using the same material.

Table 2: Mass Spectrometer from Mars 96

Energy ranges	Energy per charge 50eV-35 keV Mass 1-100 amu
Resolution	Energy per charge 5% Mass per charge 6% Mass 10% Angle in spin plane 5° Angle perpendicular to spin plane 12°
Field of view	Instantaneous 5° x 360° After ½ spin 360° x 360°
Pointing	Direction FOV plane parallel to spin axis Mounting accuracy 0.5° Knowledge accuracy 1°
Mass	Sensor 4 kg Dedicated electronics 0.4 kg
Dimensions	12cm x 12 cm x 15 cm
Power	4 W

Telemetry	500 b/s
Temperature range	Operation -20/+50° C Stand-by -40/+70° C

Neutron spectrometer

Table 3: Neutron Spectrometer Specifications from Mars 96

Energy range	0.001 eV to 1 MeV
Min. detectable water content	0.1 wt. %
Data capacity	300 bit/2.5 hours
Power consumption	0.25 W
Mass	0.2 kg
Session time	2.5 hours

Gamma Ray Spectrometer

Table 4: Specifications from Mars 96

Gamma-radiation energy range:	0.3 to 0.8 MeV
Energy resolution for Ev = 0.661 MeV	better than 8%
Measurement for accuracy: For major rock-forming elements For minor elements	 better than 10% better than 20%
Data capacity	10 kbits/h
Power consumption	1.2 W
Mass	0.8 kg
Session time	10 hr

X-Ray Spectrometer

Table 5: Specifications from Mars 96

Energy range	1 to 24 keV
Data capacity	10 kbit/10 min
Power consumption	0.9 W
Mass	0.4 kg
Session time	0.5 hr

Microscope imager

As our prior scientific objective is to search for life, the ability to image micro-organisms such as bacteria seemed essential. The chemical composition of the sub-surface would tell us if there is a potential form of life in the rocks, but an image of such micro-organism would be the only valuable proof that there is or has been life on Mars. Unfortunately, the dimension of a bacterium is only 20 to 500 nm, which requires an electron microscope to be observed and imaged. It turns out that an electron microscope weighs at least 150 kg, which is much too heavy to be on board of a spacecraft. Thus, the detection of life must rely on chemical analysis.

Weather station for temperature, pressure, humidity

Valley Marineris is a warm, humid, high pressure are compared to the rest of the surface of Mars due to the fact that the bottom of the valley is 7 km deep. Clouds have even been observed in the early morning. Thus it would be interesting to measure temperature, pressure and humidity of the atmosphere. It would represent a discriminative element concerning the possibility of life.

These instruments allow the in-situ measurements of meteorological parameters on the surface of Mars. They will measure temperature, pressure, wind direction and speed, and the humidity of the atmosphere.

Table 6: Scientific Data Measurement Ranges and Energy Costs

Temperature	140 K to 300 K (accuracy 1%)
Pressure	3 to 10 mbar (accuracy 1%)
Wind velocity	1 to 50 m/s (accuracy 5%)
Humidity	10 to 1000 ppm (accuracy 10%)
Data capacity	<16 kbit/day (waiting mode 1.6 kbit/day)
Power consumption	<1 W (mean)
Mass	0.4 kg
Session time	first day continuous, then periodically

Table 7: Meteorological instrumentation specifications from a hypothetical Team X project between Arizona State University, the University of Arizona and the Jet Propulsion Laboratory

Barocap Pressure sensor :	
Mass	0.016 kg
Power	3.6 mA + 12VDC
Dimensions	30 mm x 30 mm x 14 mm
Temp/Detector Power	-60° to +80° C
Builder	Viasala
Design Life	1 Martian year minimum
Inheritance	Mars Polar Lander, Beagle2

Ambient Temperature Sensor and Wind Reference Temperature Sensor :	Thin-wire thermocouple
Mass	0.035 kg
Max Data Output rate to CDS	2 Hz
Power	-6.516 mV to 1.801 mV
Peak Operating Power	1.801 mV at 303K
Indiv. Sensor Dimensions	2.5 cm x 3 cm x 0.25 cm
Junction Block Dimensions	1 cm x 2 cm x 4 cm
Temperature/Detector Power	143.15 K to 303 K
Design Life	1 Martian year minimum
Inheritance	Mars 96, Pathfinder, Viking

Wind Sensor	
Instrument Type	Hot wire resistance anemometer
Mass	estimated: 0.03 kg
Data vol./day	1000 kbits/sol
Peak Operating Power	200 mW (depends on wind speed) 600 mW is worst case
Dimensions	50 mm x 25 mm x 25 mm
Builder	FMI-Finnish Meteorological Institute
Design Life	1 Martian year minimum
Inheritance	Pathfinder, Mars Polar Lander

Camera

The camera should provide a wide-angle (48° for the camera of Beagle 2) multi-spectral stereo imaging of the landing site. The camera will help scientists study the geology of the landing site, as well as provide information on the structure and the stratification of the cliff of Valles Marineris. Solar observations could be performed to measure water vapor and atmospheric dust density. Furthermore, multi-spectral observations of Phobos and Deimos relative to the background of stars may enable us to determine the position and orientation of the Lander.

Table 8: Specifications from Beagle 2

Mass	0.360 kg
Volume	747 cm^3
Power	1.8 W average consumption
RS422 bus	10M bits/s
Pixels	1024 x 1024

Table 9: Specifications from Mars 96

Height above ground	1 m
Number of pixels	2048
IFOV	0.5 mrad

Field of regard	60° x 360 °
Spectral ranges : Blue Band Green band Red Band Near IR band	 0.44 to 0.46 µm 0.54 to 0.56 µm 0.69 to 0.75 µm 0.96 to 1.02 µm
Data Capacity	26 Mbits (2.6 Mbits w/ compression)
Power consumption	2.0 W
Mass	1 kg
Session time	-0.3 hour

Chemical and Biological Analysis Package

Specifications for the chemical and biological analysis package are still pending.

Engineering Team

Overview (LD)

The engineering team has been split into a number of different subsystems. Each of these subsystems corresponds to a specific aspect of the project, and these are based on standard spacecraft engineering decisions. Each group is responsible for two aspects of the project. The first is the transit of the spacecraft to Mars and the descent of the lander to the surface. The second is the operation of the lander on the planet surface. The groups from these projects are as follows:

Chief Engineer / Systems

The Chief Engineer (CE) is responsible for the overall functioning of the engineering team and reports to the program manager. The CE is responsible for scheduling and running meetings of the engineering team. He is also responsible for establishing deadlines, and ensuring the productivity and timeline of the engineering team.

The CE is also responsible for the overall systems integration of the spacecraft and ensuring that all of the systems interact in a manner that is most beneficial to the mission. This includes the development of the overall mass budget.

Structures

The structures subsystem is responsible for the structural design of the spacecraft. This involves the physical design of the spacecraft. The structures team will look at structural strength issues, vibration, and other issues relevant to the structural design of the transit spacecraft and the lander.

Thermal / Environmental

The thermal / environmental team is responsible for ensuring that both the spacecraft and the instruments are able to survive the harsh environment of space. This includes the effects of radiation, temperature, vacuum and other environmental effects of the space and Martian environments.

Propulsion

Propulsion is responsible for the development of the propulsion strategy throughout the entire mission. This includes thruster selection, fuel management, and other propulsion needs. The propulsion group is also responsible for the selection of a suitable launch vehicle.

Guidance Navigation and Control

The initial concern of the Guidance, Navigation and Control (GNC) group is the determination of a proper orbital trajectory for transit from Earth to Mars. Furthermore, the GNC group will look into the attitude control needed on the spacecraft.

Communications and Data Handling

The Communications and Data Handling (C&DH) group is responsible for the processing, storage and transmission of all data and communications from the spacecraft. This includes both scientific data and housekeeping information throughout the flight.

Power

The power subsystems group is responsible for the generation and distribution of power throughout the spacecraft. This group is also responsible for maintaining the power budget for the spacecraft.

Payload

The Payload Subsystem addresses the question of how the surface operations will be accomplished to reach the scientific goal. Our Payload lead is spearheading the effort to choose the best kind of machine or machines to extract samples from under the Martian surface.

Ground Operations

Ground Operations is responsible for developing an operating strategy for the spacecraft both during the transit to Mars and during operations. This includes manpower needs, personnel scheduling and the determination of the needed ground assets.

Present Status

Currently, the scientific goals have been received from the science team, and they have been transformed into design requirements. From these requirements conceptual design of the spacecraft has been started. The conceptual design process continues, and is expected to be completed by the end-of-day Friday, July 16, 2004. To this end each of the subsystems has been determining the major design drivers that will govern the design of their subsystems. Some of the information determined by these subsystems is included below. A number of feasibility studies are currently being undertaken.

According to our present work, the lander will be a stationary platform that drills at least 0.5 m and possibly 6 m into the rock at the bottom of the Valles Marineris. The drill will be either a hollow auger or a sonic drill. The power will be obtained from stationary flat panel solar arrays. These results are preliminary and are subject to change as more research is completed.

Structures(KG)

The structures subsystem will determine the structure and other related characteristics of the following three elements: 1) the transit satellite 2) the landing system vehicle, and 3) the platform that will operate on Mars. A few key characteristics are mass, size, subsystem placement, and radiation protection requirements of each of the three systems mentioned previously. Two missions, the Mars Polar Lander and the Mars Exploration Rovers (MER), will provide the basis for these designs.

Transit Satellite

The design of the satellite that will carry the platform from Earth to Mars will be based either on the MER or Polar Lander transit satellites. These two designs have already been built, tested, and flown successfully in space on previous missions, and hence both designs are very low risk. In addition, using either of these designs ensures that the satellite will fit in the payload bay of a launch vehicle. If the MER satellite design is used, then the satellite will be launched via a Delta IIs rocket. Otherwise the Delta II 7425 launch vehicle, which launched the Polar Lander, will be used.

Landing System

The landing system will depend on which transit satellite is chosen. The MER system, consisting of bouncing on giant airbags, has been proven multiple times in the past and is extremely effective. If the landing system design is based on the Mars Polar Lander, then more testing and possible design changes will be required prior to launch, due to the fact that this system failed during its attempted Mars landing.

Alternatively, if the landing system is based on the next scout mission, PHEONIX, retro-rockets will become the more probable stabilizing and landing method.

Platform

The experiment will consist of a stationary "mother ship" platform that will create a hole in the Martian surface, retrieve Martian samples from various depths, and analyze these samples. The Mars Exploration Rover may provide an adequate basis for designing the platform. Currently, the two options concerning the digging device are a pile-driving mechanism and drill. The pile-driving device will continuously drop a weight, perhaps aided by pyrotechnics, onto the Martian surface to gradually dig a hole. If specifically developed into an open-core auger, then the device will be able to pick up chunks of the surface and pull it up to the platform. In a different option, the drill will create a hole, perhaps via ultrasonic waves, but the corresponding retrieval method is unknown as of yet. Both coring methods may require scooping out the broken Martian terrain from the hole to protect deeper samples from contamination.

Thermal/Environmental (SS)

The thermal systems will be designed to accommodate the heat output from high-power devices on the lander including the scientific instrumentation and the drilling system.

Depending on the drilling system implemented, stored cryogens maybe used.

The lander will utilize silica aerogel as insulation to maintain electronics at 298 K throughout the Martian day and night. Capton shielding will be used both in space and on the lander to protect from radiation. Currently, an ablative hull will be used on the spacecraft to protect the lander against thermal entry upon insertion into the Martian atmosphere. This may change depending on the budget requirements of the mission.

Propulsion (LO)

The propulsion subsystem is responsible for the launch of the spacecraft onto a Martian trajectory and for performing trajectory corrections and Mars orbit insertion, with the intent of a surface landing. Two primary design drivers are the mission profile and spacecraft dimensions. Mission profile data includes points at which thrust will be required and the amount of thrust required for each maneuver. Spacecraft dimensions include both size and mass. Other unknowns that will be useful in design are the acceptable flight environment (vibrations, acceleration loads, etc) and the launch site.

Design of the propulsion system will begin with an assessment of past solutions. After the performance requirements are determined, both old and new propulsion systems will be considered and the feasibility of each determined. Simplicity, reliability, cost, and required escape velocity for the mission will be used to rank each system. It is anticipated that the spacecraft will be launched on a Delta-class liquid bipropellant system. This vehicle will either place the spacecraft on a trajectory towards Mars, or will be supported by an onboard propulsion system. Both onboard propulsion systems and surface landing systems are currently being investigated.

Guidance Navigation and Control (MA)

Getting from Earth to Mars includes a number of key sequential steps, including the following: launch with an expendable launch vehicle, insertion into geosynchronous transfer orbit (GTO), cruise to Mars on a Hohmann transfer, insertion into Mars orbit, atmospheric entry, and landing. The vehicle's GNC facilities will control it from deployment in GTO through touchdown on the Martian surface. NASA's Deep Space Network (DSN) will perform tracking and ranging for the Mars mission during the cruise and Mars orbit insertion phases. Momentum wheels will stabilize the vehicle during cruise, and small reaction control system (RCS) thrusters will perform the attitude adjustments. The launch is planned for the December 2011 Mars launch window. The launch and orbital maneuvers will be simulated and optimized to minimize fuel consumption and thereby, weight.

Communications and Data Handling (MA)

The Communications and Data Handing subsystem should take full advantage of available resources to provide the largest amount of data possible. The qualifier, "available resources" is not restrictive to currently available resources, but those planned to be launched in missions preceding the NASA Academy Scout Mission. The communications subsystem will then be made up of the set of proven or standardized technologies used in all preceding missions. Proposed data systems will be discussed for the following mission sections: cruise segment, landing segment, and operations segment. Research is ongoing for background information about previous and upcoming missions. Once the required information has been gathered, the subsystem will be roughly designed, pending power considerations. Current estimations are that the CD&H subsystems should be allowed at least 30 watts of power to meet with specifications, at least during the operating segment.

Cruise Segment

The Cruise segment will be based on those used successfully by the Mars rover missions. The specifications can be found on JPL's website. These will provide the specifications set for antenna design and data packaging, including health information during flight. Considerations will be regarding what additional state-of-health data ground support needs or would like for cruise monitoring. In the event that ground control needs minimal information the communications systems defined by JPL will be reduced in functionality.

Landing Segment

The landing segment will be based entirely on the system proposed for Mars Science Laboratory (MSL). The NASA Academy mission potentially plans to retro-rocket land similar to the design proposed in the MSL. The system will be reviewed more closely than that used for the transit stage because new capabilities related to real-time data transmission might allow the system to be less complicated than previous versions. We are attempting to find detailed specifications related to the mission from JPL's site to better understand data concerns or needs for successful retro-rocket landing. We are also laying out a nominal set of data necessary for a successful landing and deciding if that data should be transmitted or acted on autonomously by some other control system.

Operating Segment

During operations, communications should be able to provide capabilities based on the presence of the Mars Telecommunications Orbiter (MTO), slated for delivery in 2009. The large data rate capable by the MTO should reduce storage needs past systems may have used and allow shorter-time step measurements, providing higher accuracy data. The subsystem will probably be designed based on the MSL, but alterations will be made because of differences in equipment and communications capabilities. In ongoing discussions with the science team, we are determining which instrumentation will be used, the interfaces for that instrumentation and the collection frequency required to make measurement worthwhile.

Power (JS)

Based on NASA R&D found on the Goddard Library website, the Power subsystem has decided to use fixed, unmovable solar arrays for powering the Mars Lander as opposed to movable arrays which would follow the sun across the sky. Several papers have been published regarding this subject, and the general consensus among NASA scientists and engineers is that any light focusing and/or following techniques are not worth the time and effort to devise. Because of the amount of dust content in the Martian atmosphere the sunlight on Mars is scattered at all angles and will hit the solar array from all directions no matter what orientation and/or focusing scheme is used[1]. In addition, the benefits of a fixed array make the choice desirable; it is more robust and less complex than the alternative. Because our mission is only intended to last 90 days, the settling of dust on the arrays should not be a problem. According to some of the latest research on solar arrays, the dust will only decrease the overall efficiency of the panels by 0.28% per Martian day (a little over 24 hours)[2].

We are currently researching the possible candidate cells for the solar array and the type of batteries that will be used for the lander. Our preliminary goal is to be able to provide the Lander with ˜ 200 Watts of power for the daytime and ˜ 100 W for sleep mode at night. Of course, this will be very dependent upon the price of the components that we find.

Payload (FD)

The payload delivery system serves as a link between the environment and the instruments. This includes extracting subsurface samples, collecting atmospheric samples, and transporting the samples to the instruments. This update focuses on the extraction of core samples from between .5 and 6 meters under the valley floor which is made from basalt.

Three main challenges have been identified. First, the drilling process cannot destroy or alter the chemical properties of the sample. As a result, continuous lasers and other vaporizing methods cannot be used, unless the sample is taken horizontally away at least three diameters away from the core. Next, traditional lubrication methods may not be used for cooling and transporting slurry due to mass and contamination issues. Finally, the sample must be transported to the surface for study, giving preference to methods that can extract a core. Other engineering constraints include the size and complexity of the device, its power requirements, and its ability to complete the mission requirements in ninety days.

A LANL report[3] examined several methods for drilling large holes, on the order of 200 meters, on Mars with a power budget of 1000 Watts per day. Of these, the methods that best matched the science requirements for providing an uncontaminated core were a hollow-stemmed auger and sonic or ultrasonic drills. The auger is a more proven technology, but may require more mechanical parts. A JPL program has developed a miniature ultrasonic drill

[1] http://library.gsfc.nasa.gov/. Accessed July 13, 2004.

[2] Landis, Geoffrey A., Jenkins, Phillip P., "Dust Mitigation for Mars Solar Arrays." Twenty-ninth IEEE Photovoltaic Specialists Conference, 2002. 19-24 May 2002 Pages: 812-815.

[3] "Deep Drilling on Mars." http://www.ees4.lanl.gov/mars/. Accessed July 13, 2004.

that runs at 24 Watts for shallow (on the order of 10 cm) Martian work, suggesting that scaled versions may be available for the current mission needs.[4] Also under consideration is a variation on the 'mole' sent on Beagle 2; however, that tool was designed to burrow through regolith, not rock. These three methods will be researched in more detail to make a final determination.

Ground Operations (DA)

The Ground Systems/Operations Subsystem will consider three major decisions: 1) choosing ground-based facilities and equipment to meet mission monitoring requirements; 2) describing the work schedule for the ground team while the spacecraft is en route to Mars; and 3) describing the work schedule for the ground team while the payload is operating on the surface. For the first category, decisions will be based on the current infrastructure of Mars missions' ground support and information from the manual, *Space Mission Analysis and Design.* The plan will include the equipment to be used, the approximate price of ground support and any agreements between agencies/contractors that may be required. Existing facilities will be pinpointed instead of developing a dedicated ground station for this mission. The second and third categories will involve interfacing with the propulsion, payload, science and communications subsystems. In particular, the parameters that determine ground support's role during surface operations will come from science and payload. These parameters will be used to determine the frequency of commands sent, the method and equipment for sending and processing mission data and the requirements for keeping track of spacecraft health.

Program Team

Cost Estimation and Budget Concerns (CM & NH)

NASA has assigned $400 million as the maximum cost of a Mars scout mission for the 2011 opportunity. In response to the NASA assignment, the Academy mission will cost less than $450 million at the completion of the design phase.

Space Mission Analysis and Design outlines three cost-estimating methods.[5] The first, analogy-based method is described below. The second method uses detailed bottom-up cost estimation to construct the cost of the mission by adding up the cost of individual mission components. The third, parametric estimating method, uses Cost Estimating Relationships (CERs) to mathematically determine the cost based on quantitative mission parameters. To improve the accuracy of cost estimation and increase the academic benefit of budget process, all three methods will be used and compared to each other. The analogy-based method has already been completed and is described below. The analysis will be modified for any

[4] "Ultrasonic/sonic drilling/coring (USDC) for planetary applications." http://ndeaa.jpl.nasa.gov/ndeaa-pub/SPIE-2001/Paper-SPIE-4327-55-USDC.pdf. Accessed July, 13, 2004.

[5] *Space Mission Analysis and Design*, 3rd Edition. Ed. James R. Wertz. Microcosm Press, 1999.

changes to the mission architecture. The second and third cost-estimating methods will be completed as mission architectures are proposed to the design group.

To perform this analysis, we looked at the requirements for five previous Mars missions. We took cost data from these missions and used it to estimate the cost of the Accademy mission. This is the analogy-based method of cost estimation.

Pathfinder addressed key engineering issues involved with landing and operating a rover on Mars at low cost. Its scientific instrumentation included an imager, meteorology equipment, and an alpha proton x-ray spectrometer.

Mars Odyssey was a medium-cost orbiter mission launched with a substantial scientific package package that included a thermal emission imaging system, a gamma ray spectrometer, and a Martian radiation environment experiment.

Mars Express was developed by the European Space Agency to perform valuable Mars science at low production cost. Its science instrumentation included a high resolution stereo camera, an energetic neutral atoms analyzer, a fourier spectrometer, visible and infrared mineralogical mapping spectrometers, a subsurface sounding radar altimeter, a radio science experiment, an ultraviolet and infrared atmospheric spectrometer, and the Beagle 2 probe.

Mars Polar Lander was an unsuccessful mission developed to study the planetary features of the polar regions of the Martian surface. Its instrumentation included a microphone, meteorology equipment, a thermal gas analyzer, a mass spectrometer, a stereo camera, and a light detection and ranging experiment.

Mars Global Surveyor was developed at very low-cost with a modest scientific package that included a camera, altimeter, magnetometer, and celestial sensor.

Viking, by far the most costly unmanned mission, was developed at a cost equivalent to approximately three billion 1997 dollars. The Viking mission included multiple craft units, and its scientific payload consisted of two seismometers, a gas chromatograph, x-ray spectrometer, mass spectrometer, meteorology equipment, cameras, thermal imagers, and orbital water detectors. The multiple spacecraft units, as well as the extensive mission timeline and high reliability of spacecraft operation contributed to this large cost.

Comparing the proposed Academy scout mission to these examples, the scientific and engineering requirements of the mission fall far short of the demanding Viking mission. At the same time, the landing requirements and coring method of the Academy mission exceed the requirements of the Global Surveyor, Pathfinder, and Odyssey missions. The platform is very similar to the Polar Lander, but the sample preparation required in the Academy mission will add additonal engineering complexity. For these reasons, we estimate the cost of the Academy mission as proposed to be approximately \$500 million, with an uncertainty of +\$150/-\$50 million.

Education and Outreach (JM & AB)

Objective

The goals of the education and outreach team are to help the general public understand the value of our mission which, as scientists and engineers, we feel is intrinsically important, and to get students interested and excited about studying science and engineering. Our team wants to convey the message that searching for life on Mars is both an exciting endeavor and an investment in the future.

Approach

General Public

The public is most concerned with justifying the scientific return with the cost, risk, and necessity of the mission, and the hardest question to address is the one most likely on the public's mind: "How does going to Mars benefit people on Earth?". It is important to note that the answer is not "There is no benefit." Instead, it is "We do not know," and this is the driving force behind campaigning the Mar Scout Mission as an investment in the future. The journey to Mars and the technological bounds it will take to get there will raise questions that we cannot even imagine right now. The driving focus of our outreach team will be to assert that going to Mars is an investment in the future, that the benefits will be bountiful, and that inconceivable questions will be answered.

The campaign will be multimedia including a PowerPoint slide presentation and radio show that explains the importance of doing science and taking risks even if a direct benefit to life on Earth is not yet known. It will include historical instances that show how the journey on the road of curiosity and discovery is filled with unexpected discoveries and technological advances that otherwise might not have come to be. For example, scientists studying microbial life have recently learned that they can use biological processes of some bacteria to make new types of fuel cells or detect pollutants in the air. In the same way, searching for life on Mars for the sake of scientific inquiry will undoubtedly lead to scientific knowledge foundational to new technologies and applications for humanity.

Another idea to justify going to Mars to the public is considering the mission as a way to discover our roots. The idea is to explain that most families are interested in determining their family history by knowing who their ancestors were and where they came from. Similarly, scientists are interested in knowing the history of life on earth, and there is evidence that the original seeds of life were brought to the Earth via meteoritic impacts, which may have originated on Mars.

Students

The outreach approach for students relies on the natural excitement surrounding ventures that are outrageous, difficult, or risky and will mainly take the form of an educational web module. The main page of the module will contain information specific to the Mars Scout Mission science objectives and engineering technologies along with links to relevant sites on the following topics: 1) past, present, and future Mars missions, 2) astrobiology, 3) extremophiles, and 4) any websites referenced by the science and engineering teams. In addition, there will be a Mars Scout Mission "Fast Facts" page that is printable and summarizes the most exciting aspects of the group project.

Test and Validation (SK)

Objective

The objective of this subsystem is to make sure that the craft that is sent up into space is of high quality. Making sure that the configuration of the system lies within the standards set forth in the MIL Q 9858A is part of verifying that the platform will work once in the Martian and vacuum space environment. The MIL Q 9858A describes the quality assurance for military programs. Testing and validation also encompasses making sure that the equipment and instruments being supplied from the various vendors are compatible with our programs and sufficiently tested within the constraints set forth for the mission.

Tests

There are a variety of tests the structure must undergo before the craft can be deemed flight ready. Structural tests include static loading tests and modal surveys. Deployment tests involve solar array testing, antenna testing, and appendages testing. Vibration testing consists of acoustic testing and vibration by low frequency sine waves. Pyro-shock tests involve firing the ordinance in order to test the mechanical deployments on the platform. Payload testing includes testing of all of the instruments on board.

Testing the Mars Scout Mission platform will involve integrating many subsystems as well as managing the configurations of equipment. It is an essential part of the mission which helps ensures the success of the final product.

Approach

Qualifying the craft includes simulating and testing each spacecraft function and all of the environmental effects the spacecraft may encounter according to the following steps.

Step 1: Identify a spacecraft and payload functions

a. The payload and their main functions have now been identified; however, the spacecraft and or platform has yet to be determined.
b. Testing of the spacecraft and payload function for assurance on proper operation need to be performed.

Step 2: Identify the environment

c. Identify environment for transportation, storage, launch, and orbit vibration, shock, temperature, vacuum and radiation amounts
d. Calculate values for these environments

Step 3: Correlate functions and environments

e. Test all of the operating equipment that will be powered during launch and during the spacecraft vibration and check all modes of en route operation.

Step 4: Identify main configurations:

f. This includes boost configuration and orbital configurations and flight paths

Step 5: Devise functional tests for each major configuration

g. Test all software and equipment in configuration to assure compatibility

Step 6: Layout a sequence of functional tests and environmental testing:

h. Tests will be performed in the following order:
   1. Functional test
   2. Vibration
   3. Functional test (for verification and redundancy)
   4. Shock
   5. Functional test
   6. Thermal vacuum functional test during exposure
   7. Flash X-ray functional test

Step 7: Identify span times and special facility requirements

i. The life span of this mission has been set for 90 days + en-route time to Mars

Organization